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THE GEOLOGY OF MULLET LAKE

by

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ABSTRACT

This project was undertaken in order to establish the nature and distribution of the Mullet Lake sediments and to determine the main factors responsible for this distribution. To accomplish this a number of bottom samples were analyzed chemically for calcium carbonate and mechanically for sediment size distribution. With a few exceptions the results showed, with increasing depth of water, a gradation from medium sand to clay and an increase in the percentage of calcium carbonate. The greatest deviation in grain size occurs in one of the deeper parts of the lake where medium sand is completely surrounded by clay and silt; it is believed that the absence of the finer sediments is due to the agitating action of spring water percolating into the lake. Other irregular distributions are due to position of river inlets and outlets, current and wave action and composition of near shore material.

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INTRODUCTION

Many of the lakes so common in the glaciated terrain of North America were formed during some phase of Pleistocene glaciation. The larger lakes are often oligotrophic and support a large faunal population. Often the lake bottom is composed of loose sediments generally coarser near shore and finer in the deeper recesses of the lake. As the shoreline material is often composed of unconsolidated glacial deposits post glacial erosion by wave and current activity has, in many instances, modified the original glacial shoreline causing much of the eroded material to be deposited within the lake basin. Additional clastic material may be supplied by rivers flowing into the basin. Marl beds are often encountered accumulating in the near shore zone especially in the backwater areas (Ruttner, 1953, p. 167).

In order to determine some of the factors controlling the nature and distribution of the sediments collecting in large lakes in glaciated regions a study was made in Mullet Lake, Cheboygan County, Michigan.

DESCRIPTION OF THE AREA

Mullett Lake with an area of 26.8 square miles is the largest of a chain of inland lakes situated in the Cheboygan river basin of Emmet and Cheboygan Counties, Michigan. The lake is oblong in

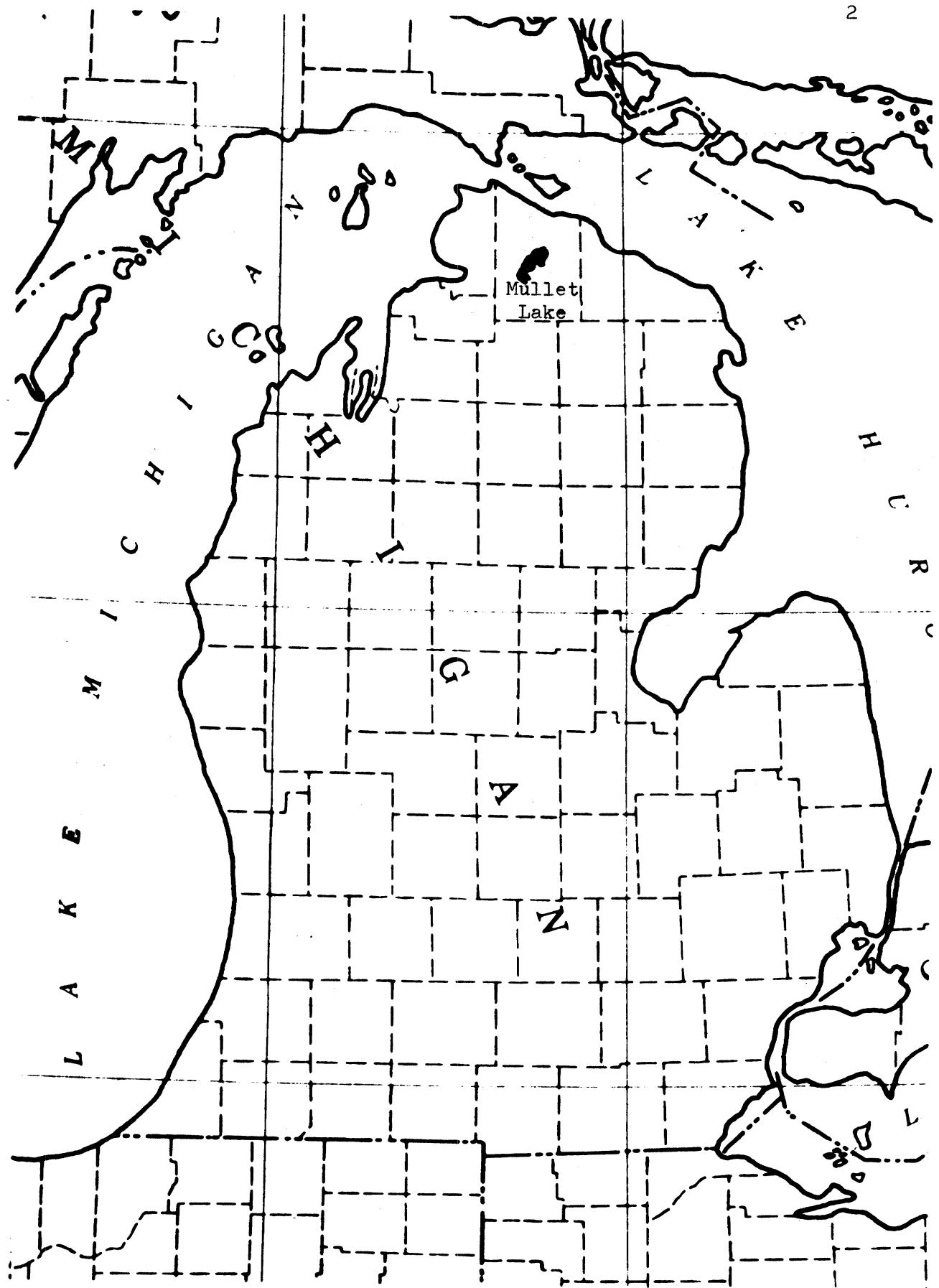


Figure 1. Map of Michigan showing location of Mullet Lake

shape and has a northeasterly orientation. Its length is slightly over nine miles and its width varies from one and a half miles to three miles (Scott, 1928, p. 88). No bedrock outcrops are known in the immediate area and the entire lake is surrounded by glacial deposits. Scott (p. 88) believed that the Mullet Lake Basin was already in existence prior to the last advance of the Wisconsin ice age. However, Spurr and Zumberge (1956, p. 96) believe that the present topography of the Cheboygan River Basin owes its origin primarily to these two factors: (1) insitu stagnation of a thin ice sheet that overrode the area during the Valders Glaciation; this gave rise to such meltwater features as ice blocks, meltwater channels and outwash plains; (2) later modification of the glacial topography by three succeeding lake strandlines. During the time of ice stagnation Mullet Lake was part of a meltwater channel which flowed northward into Lake Huron. As melting continued a series of glacial lakes formed over much of the route now occupied by the modern inland lake system. These lakes stood somewhat higher than the present level and were responsible for the well developed terraces which encircle the lake system.

The bottom topography of Mullet Basin is characterized by three distinct features:

- (1) A broad shallow expanse situated northeast of a line joining Needle and Dodge Points where the water is rarely over 30 feet deep.

- (2) A line of shoals marking the southwestern margin of this shallow area.
- (3) A well defined steep-walled trough which occupies the central portion of the lake. Depths in the trough are in excess of 100 feet, the maximum being 120 feet.

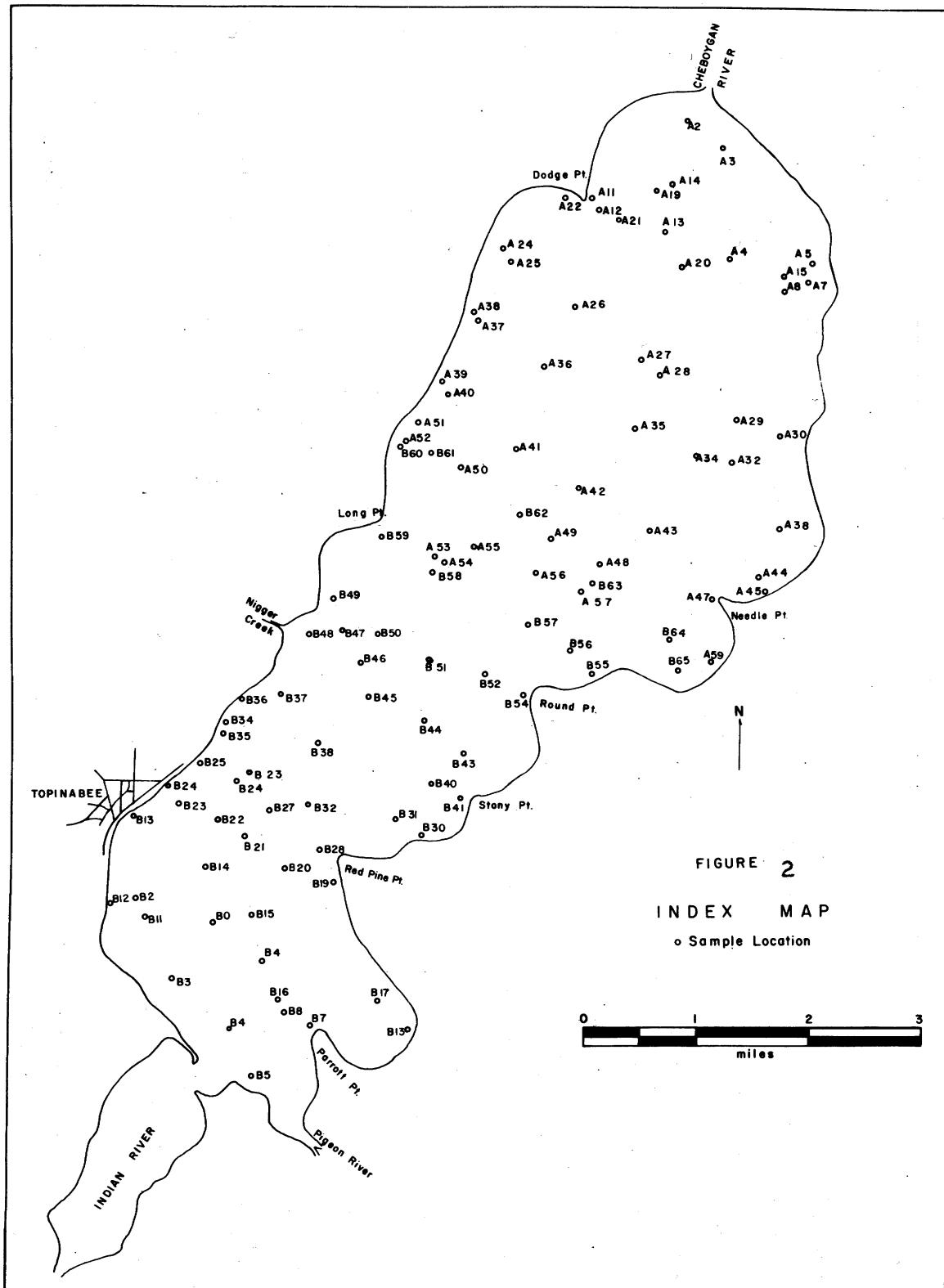
SAMPLING PROCEDURE

The Mullet Lake bottom sediments were collected during June and July of 1956 by members of the Great Lakes Research Institute.

A Peterson dredge was used to obtain the samples. The dredge was lowered by manila hemp from a small boat. When the dredge came to rest on the bottom the boat was maneuvered until the line was as close to the vertical as possible. At that position the depth was noted from the hemp line and the trigger mechanism was released.

In the open position the dredge rests upon a square foot of the bottom surface. When the trigger is released, the two halves of the scoop are drawn together enclosing about 0.3 cubic feet of sediment.

The dredge was then raised and brought into the boat where the sample was quartered and a portion of each quarter preserved in pint sized Mason jars. An excess of water was left in every sample jar to slow oxidation, and formalin was added to prevent bacterial action.



In order to establish the distribution of bottom sediment types an accurate location of each sample station is necessary. Consequently at each station a sextant fix was taken on three known landmarks on the shoreline and the station position was plotted on a United States Lake Survey Chart of 1920.

LABORATORY PROCEDURE

Because of the four year time lapse between sediment collection and sediment analysis many of the samples contained little or no moisture. As a result all of the fine grained samples and some of the silty samples had hardened into a brick-like mass. Rather than chipping out enough of the top layer to analyze, the sediment was thoroughly mixed and from this a representative sample was drawn for analysis. To achieve this, distilled water was added and the sample was allowed to sit overnight or until it could be stirred. From the stirred mixture a 100 gm. sample was taken for the hydrometer analysis.

SEDIMENT SIZE ANALYSIS

In order to determine the size distribution of each sample both hydrometer analysis and Rapid Sand Analysis were employed. These two analytical techniques are based on the relation between

particle diameter and its settling velocity in water. The general relation being that for a mixture of grains of varying size but of equal specific gravity the larger grains will settle faster than the smaller ones.

In the hydrometer technique the grain diameter-settling velocity relation is established in the following manner. When a hydrometer is introduced into a solution it measures the density of the solution above its center of buoyancy. As the density decreases, due to the passage of more and more grains below the center of buoyancy, the hydrometer settles lower and the distance from the surface to the center of buoyancy increases. The concentration (grams per liter) and grain size can be accurately estimated from the hydrometer reading and time of settling, if at a certain time after the hydrometer is introduced the meniscus level is read on the hydrometer scale, and the distance from the scale to the center of buoyancy is known from calibration of the hydrometer. The equivalent diameter of the largest grain remaining in suspension above the center of buoyancy can be calculated using Stokes Law which relates the settling time and distance.

(See Calculation Procedures)

Laboratory experiments (Ruby, 1933, p. 331) have shown that grains larger than about .06 mm. do not follow the prediction of Stokes Law. Therefore, the size distribution for the sand fraction was determined by the Rapid Sand Method as determined by Emery

(1938, p. 105). The analysis is made by injecting a 3-5 gram sample into a long column of water observing the amounts of material reaching the bottom during successive predetermined time intervals. A complete analysis requires about five minutes. Reproducability averaged 4% for 20 samples of Mullet Lake sediments, not as good as that to be expected from sieving where the average variation is 2% (Emery, 1938, p. 111).

Emery calibrated the settling tube by introducing a sample previously sized by sieving. The sample was reconstituted and twice allowed to settle in the tube. For the first run only the total height of the sediment column was noted. From this the volume percentage of each size fraction could be calculated as a function of height. For the second run the elapsed time necessary for each size fraction to settle was noted. From timings obtained in this manner the velocities of all size fractions may be calculated. A grain assigned to a certain size value may not have the diameter of that value but it does have the same settling velocity as a quartz grain of that diameter (Emery, 1936, p. 106).

HYDROMETER ANALYSIS PROCEDURE

All the samples except those composed entirely of sand were analyzed for size by the hydrometer method according to the

following procedure. The sample was reduced to 100 grams if sandy or 50 grams if silty or clayey and thoroughly dispersed in a large beaker containing 125 milliliters of a dispersing agent (45.7 grams of Calgon sodium hexametaphosphate buffered with Na_2CO_3 dissolved in a sufficient amount of distilled water to make a liter of solution). The mixture was stirred with a glass rod and allowed to slake overnight to insure complete dispersion. The slaked solution was then washed through a 1 mm. sieve and stirred for 5 minutes with an electric mixer. The dispersed sample was then placed in a 1000 ml. graduated cylinder and distilled water added until the cylinder contained one liter of mixture.

The sample was thoroughly mixed by placing the palm of a hand over the cylinder mouth and upending the cylinder several times. The cylinder was then carefully placed on a level table. If shaking created a layer of froth, a few drops of amyl alcohol were added to disperse it before inserting the hydrometer. Temperature and hydrometer readings were taken at the intervals of 40 seconds, one minute, two minutes, five minutes, 15 minutes, 30 minutes, one hour and two hours.

Following a suggestion by Reid (Personal Communication), the author devised a routine whereby five samples could be analyzed in two hours and thirty minutes. After each analysis the residue which had collected in the tube was poured into a small screw top

jar along with sufficient water to prevent drying and was put aside for later Rapid Sand Analysis.

RAPID SAND ANALYSIS PROCEDURE

The samples retained from the hydrometer analysis were elutriated to remove the finer particles. In the case of the sand samples elutriation was not necessary as they were remarkably free from finer material. Each sample was then reduced to 3-5 grams by the Jones microsplitter. Samples were then introduced into the Emery tube by means of a plunger type release device. At the instant of release a clock-timer was started and the height of the accumulating sediment was noted at time intervals, which, for the water temperature, correspond to Wentworth class limits. During the settling process the lower end of the tube was tapped lightly with a rubber tipped rod to maintain a relatively even surface of the accumulating sediment column.

HYDROMETER THEORY

The grain diameters are calculated from the data obtained by the hydrometer analysis by using Stokes Law which is usually written in the following manner.

V = velocity of particles in Cm/sec.

P_g = density of particles in Gm/Cm³

$V = \frac{2(P_g - P_f)g}{9N}$ P_f = density of the fluid

$9N$ G = acceleration of gravity

r = particle radius (Cm)

N = fluid viscosity

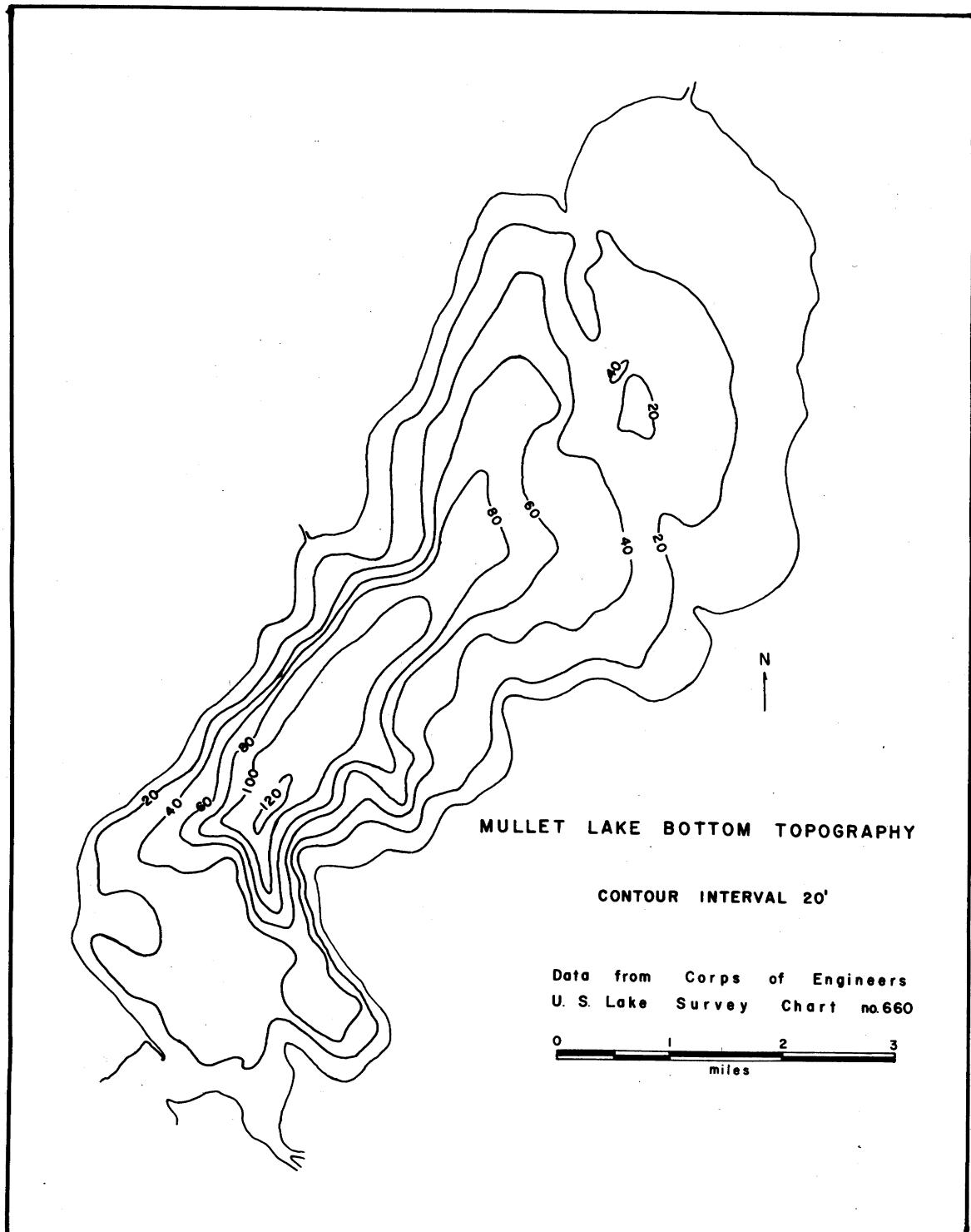
The hydrometer analysis gives the settling velocity of the largest grain remaining in suspension above the center of gravity after a certain time interval. This velocity is expressed as Zr/T where Zr = distance in Cm from surface to center of buoyancy, T = elapsed time. In this case the density of the particles was considered to be 2.65 (the density of quartz). This may not hold for those fine grained sediments having a high $CaCO_3$ content however the correction factor is so small that using 2.65 appears justified. The properties of the fluid P , N are temperature dependent. In view of this Stokes relation can be written $V = Kr^2$ (Briggs Laboratory Manual). Substituting for V and solving for d (in mm) leads to $d = (400/K)^{1/2}(Zr/T)^{1/2}$. To facilitate this computation a graphical solution to this equation was derived and a family of curves constructed which relate d to $(Zr/T)^{1/2}$ at the temperature ranges encountered in the analysis where K is a function of temperature alone and is equal to $K = 359.5/N$.

The data from the hydrometer analysis were grouped into Wentworth size classes. Where the class limits did not coincide

with the sizes obtained at each reading they were obtained by interpolation. These classes were then combined with the results of the Rapid Sand Analysis. From these data the median diameter, quartile deviation, skewness and kurtosis for each sample were computed. These calculations were made with the Pure Frequency Function Computer Program available at the Subsurface Laboratory, University of Michigan.

INTERPRETATION OF SIZE DISTRIBUTION

Figures 4 and 5 illustrate the relative distribution of the sediments which comprise the floor of Mullet Lake. In general, the sandy well-sorted sediments are restricted to the shallow near-shore areas while the poorer sorted clays are present primarily in the deep central lake trough. The width of this near-shore sandy zone varies considerably with respect to its position in the lake. It is widest in the northern part of the lake where it occupies the entire area northeast of a line joining Dodge and Needle Points. To the south of this area the zone becomes increasingly narrow on both sides of the lake and in the southern portion the sand is present as a narrow strip extending only a few tens of feet from the shore. Also in this southern region the clay-size particles are not restricted to the central trough and cover much of the broad shallow shelf south of the trough (See Fig. 4).



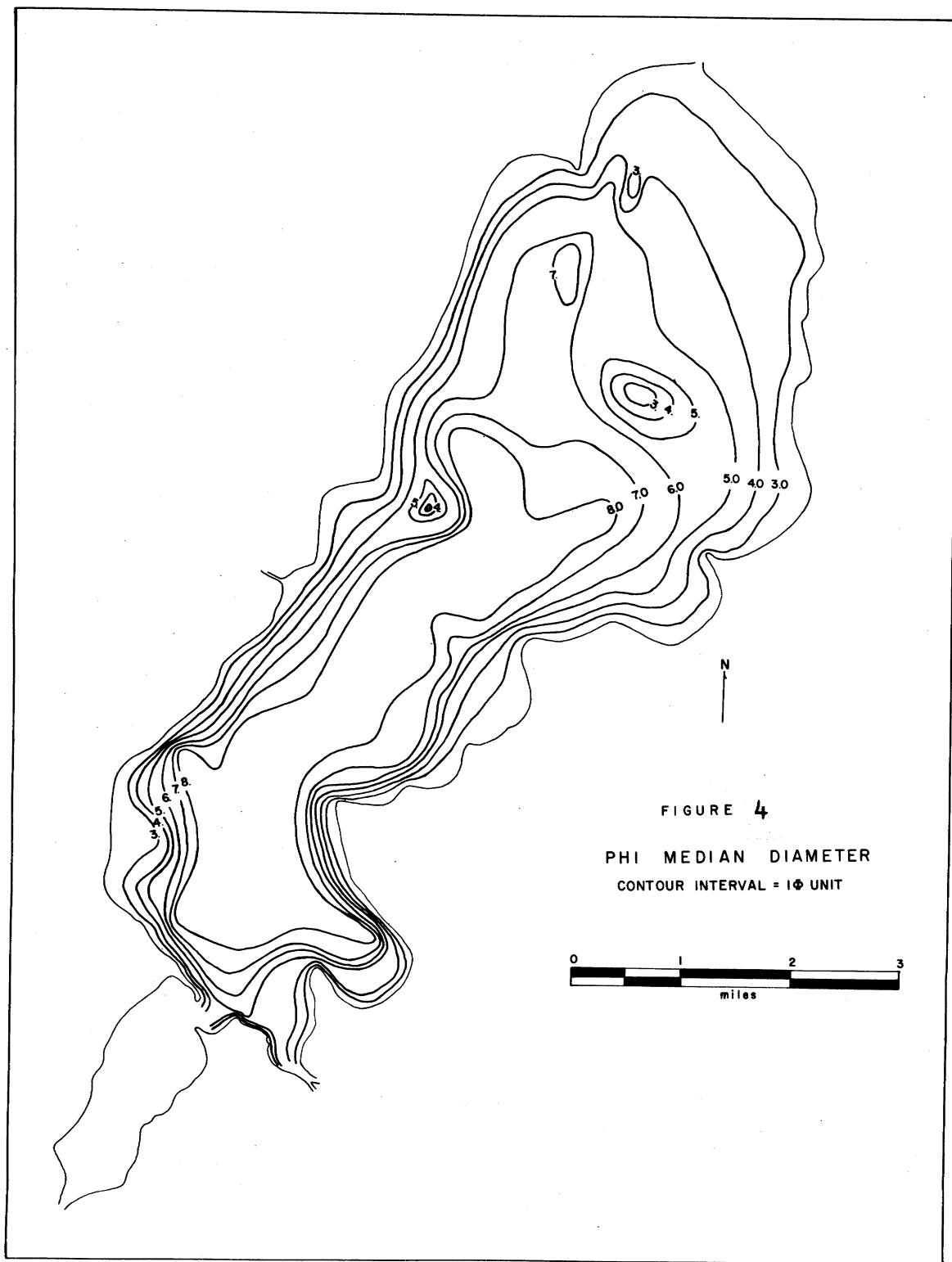
In addition to this general sediment pattern there are several areas of limited extent that show irregular distribution.

Several explanations are possible, such as position of river inlets and outlets, current and wave action, and composition of near-shore material, and the presence of springs.

Several hundred feet offshore from Long Point and at a depth of about 100 feet there is a small area of sand-sized particles which is completely surrounded by fine silt and clay (Fig. 4). Between Dodge and Needle Points the sediments vary from coarse sand to silt over short distances.

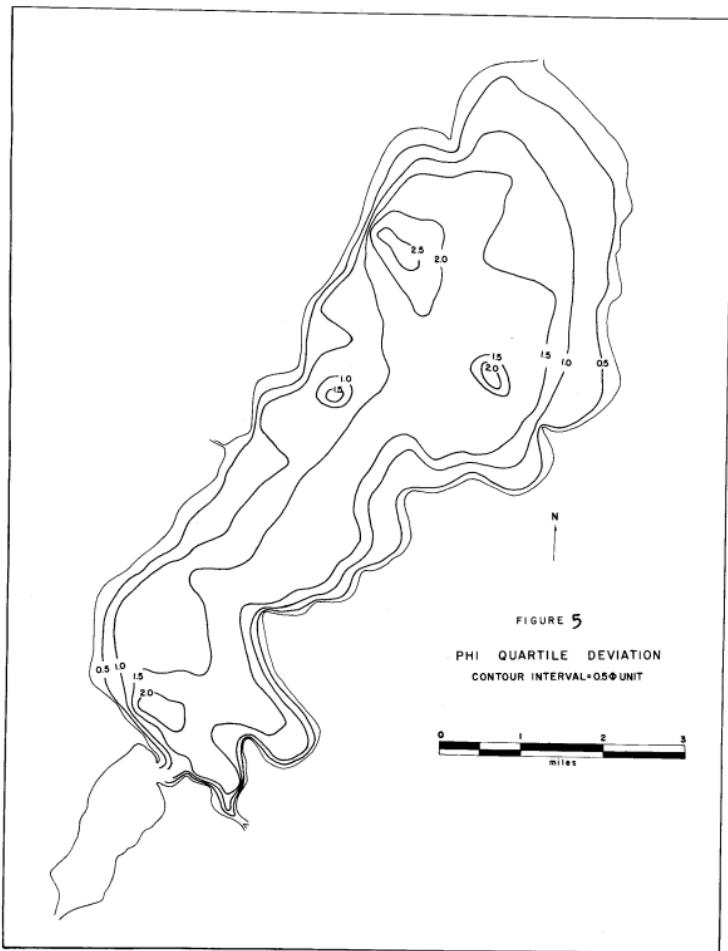
The origin of the small area of sand entirely surrounded by clay which is present in the deep waters offshore from Long Point is difficult to explain. The area itself lies in a small depression, a natural site for deposition. Possibly it is the location of a spring. The agitation caused by the spring water percolating into the lake could sweep the fine sediments into more quiet water.

The large amount of near-shore clay and silt accumulating in the southern end of the lake may in part come from the debris being carried into the lake by Indian River and Pigeon River. These are both sluggish rivers which drain swampy areas immediately prior to flowing into Mullet Lake, hence the load transported into the lake by these two rivers probably consists primarily of



silt, clay, and organic debris. The only other stream flowing into the lake is Nigger Creek which is located on the western shore. Like the other rivers this stream is sluggish and drains a swampy area immediately before entering the lake. In this instance, however, no clay or silt is presently accumulating lakeward from the stream mouth. The sand spits that are presently being built around the stream mouth indicate active currents and it is probable that fine grained material brought in by Nigger Creek is swept away by these currents. In support of the idea that the rivers contribute the fine-grained sediment to the lake is the predominantly sandy bottom in the northeastern section of the lake where there are no river inlets.

The presence of such features as wave-cut cliffs, boulder pavements, spits, and sand bars indicates that currents and waves are active. The location of these features outlines in a general way where these processes are in operation. Boulder pavements and wave-cut cliffs are common on the eastern shore and the wave action responsible for their formation is also primarily responsible for the well developed sand zone. Since the lake is situated in the prevailing westerlies belt, the general direction of wind movement is from the west. In addition, the storm winds blow from the northwest (Year Book of Agriculture, 1941, p. 924). As a result of such winds the strongest wave action would take place on the eastern shore, carrying away the



finer material and leaving behind a concentration of sand-sized particles. The presence of spits on the west side of Indian River and around Nigger Creek plus a few small wave-cut cliffs indicate that waves and currents also act on the western shore and produce at least part of the sand located there. Because of their location with respect to the prevailing wind, both the southeast and northwest portions of the lake should be areas where currents and waves significantly diminish and finer sediments accumulate.

A third factor pertinent to sediment distribution in the lake relates the rock and soil composition of the land comprising the shore and near-shore terrain to the adjacent lake sediments. Along the western and northern shore sandy terraces mark the higher levels of earlier lakes (Scott, p. 91). Possibly the terraces extend some distance into the lake and the sandy zone in this region may be a feature inherited from shorelines of earlier lakes. Some sand zones are connected to glacial outwash plains. The extraordinary wide sand zone northeast of Dodge and Needle Points abuts on inland terrain of stratified sand which Scott identified as an outwash plain. It is possible that the sand zone represents the lakeward extension of this outwash plain.

From Needle Point to Indian River the near-shore material is predominantly till and the sand zone here must owe its origin to the work of waves and currents. This view is supported by the

narrowing of the zone to the south where wave action is diminished.

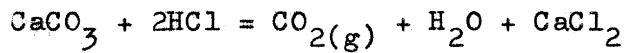
CALCIUM CARBONATE ANALYSIS

The apparatus used to determine calcium carbonate content was patterned after a standard alkalimeter. The modifications consisted of removable acid chambers which considerably reduced the time necessary for cleaning the sample chamber. The device consisted of a 100 ml. Erlenmyer flask into which the sample was placed and a separate acid chamber to hold the hydrochloric acid. This acid chamber fit securely in the neck of the Erlenmeyer flask by means of a two hole stopper. Attached to the Erlenmeyer flask by a thin aluminum collar is a drying chamber filled with concentrated H_2SO_4 , and this is connected to the outlet of the Erlenmeyer flask by a short length of rubber tubing.

The following procedure was employed in the CO_2 determinations. Thirty ml. of 4 N HCl was added to the acid chamber above the Erlenmeyer flask and the drying chamber was about half filled with concentrated H_2SO_4 . In the sample chamber itself was placed a small cylindrical metal rod (for stirring the sample) and a few drops of water. The entire apparatus was then weighed on a Nettleton self-adjusting balance to 0.01 gram. Next a small amount

of sample was placed in the sample chamber and the apparatus again weighed to determine the sample weight. The sample weight is restricted to 5 grams or less in order to insure complete reaction between the HCl and carbonate mineral present. The HCl was slowly introduced and constantly agitated during the reaction by means of a magnetic stirrer. When reaction ceased, compressed air was forced through the apparatus to displace the heavier evolved CO_2 and water vapor. The apparatus was again weighed on the Nettleton balance to determine the loss in weight. The loss in weight represents the CO_2 produced by the reaction since the evolved water vapor should have been absorbed in the H_2SO_4 chamber. Weight of the carbon dioxide was used to calculate molecular equivalent weight of CaCO_3 from which the percentage of CaCO_3 in the samples could be calculated.

The following equations and calculations were used in determining the percentage of CaCO_3 .



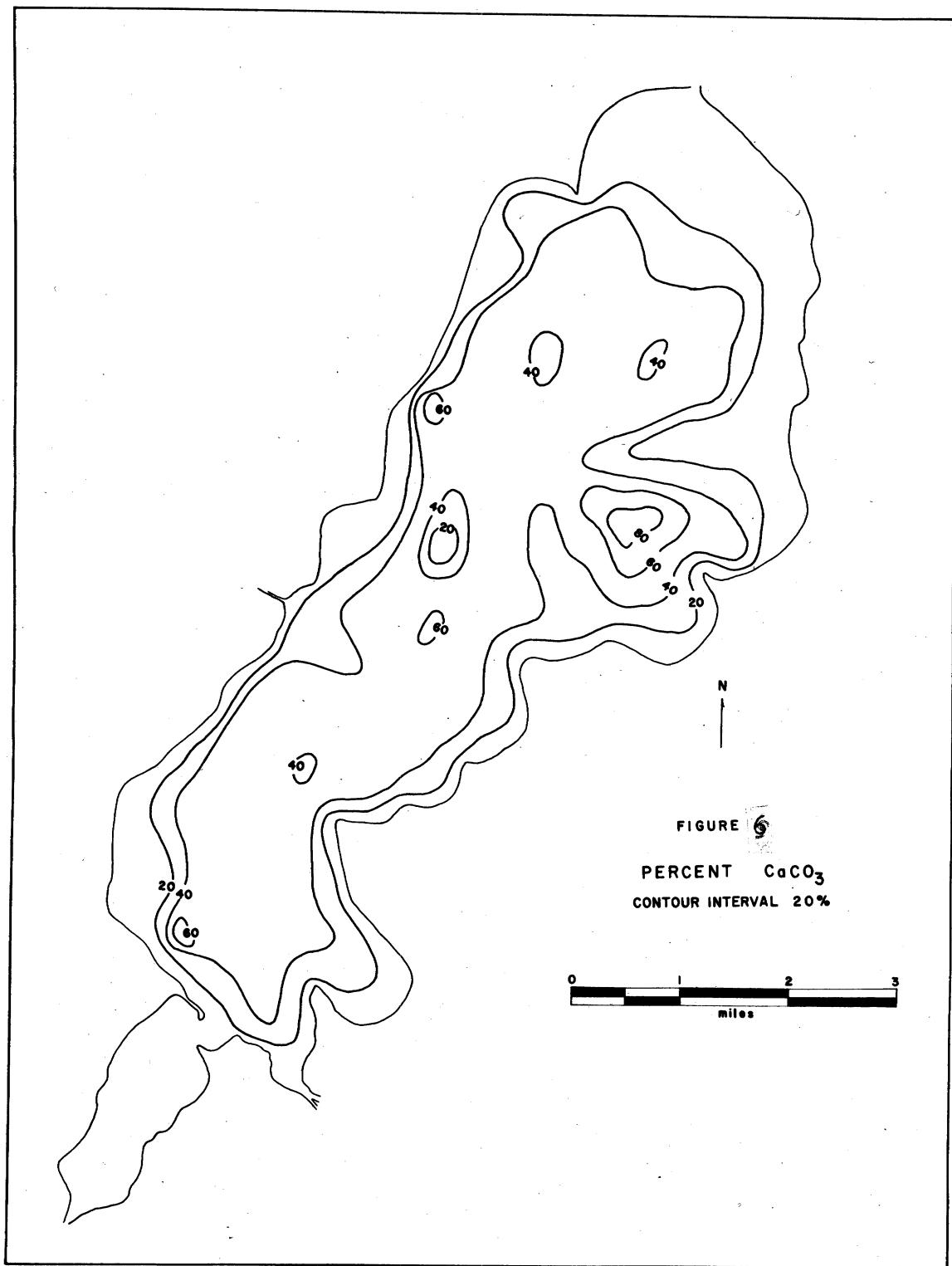
$$\text{Molecular weight } \text{CaCO}_3 = 100.09$$

$$\text{Molecular weight } \text{CO}_2 = 44.01$$

$$\text{Weight } \text{CaCO}_3 \text{ in sample} = \frac{100.09}{44.01} = 2.274 \text{ weight of } \text{CO}_2 \\ (\text{loss in reaction})$$

$$\% \text{CaCO}_3 = \frac{\text{Wt. } \text{CaCO}_3}{\text{Wt. initial sample}} \times 100$$

Inaccuracies in the analysis may result from splattering due to



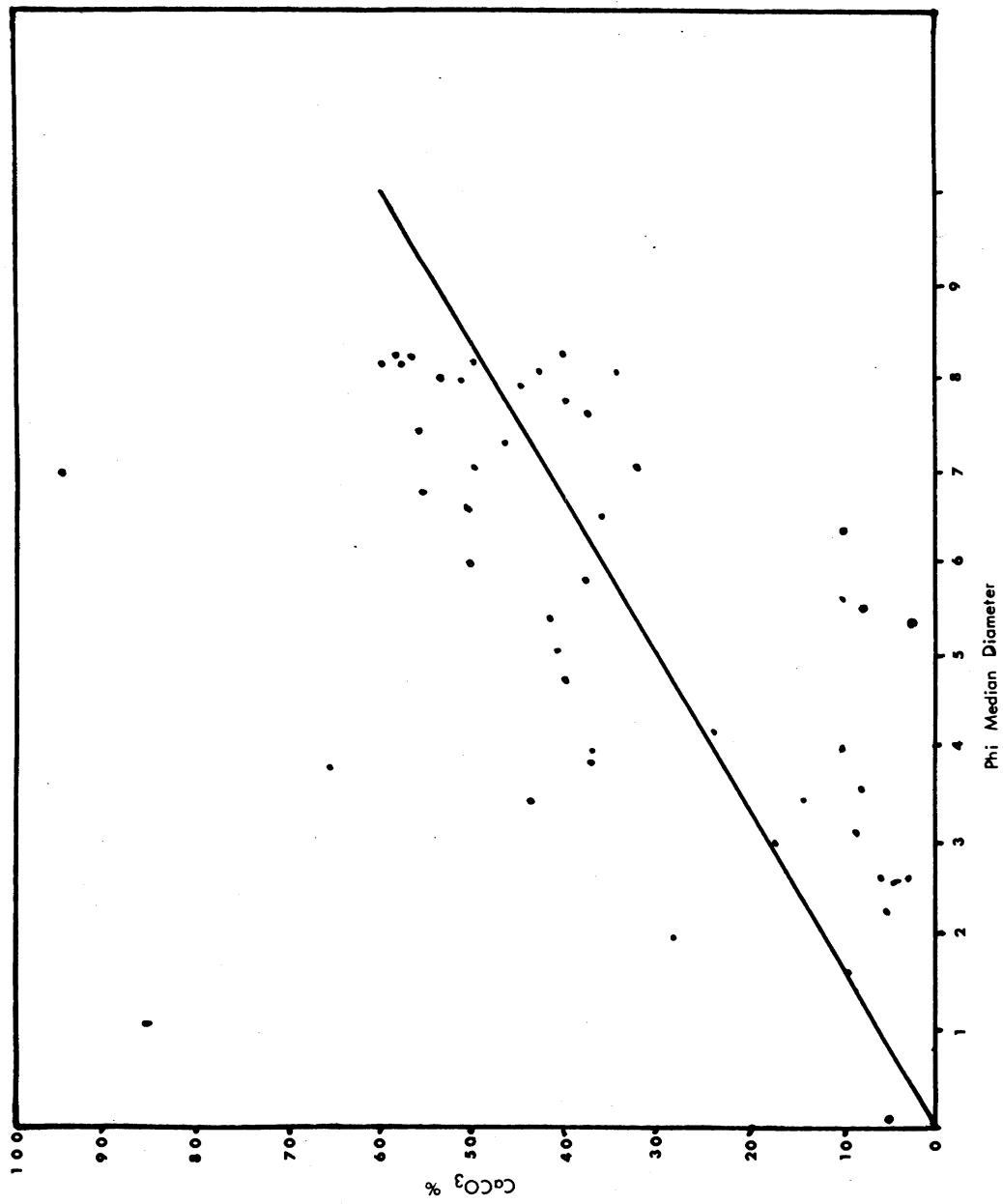


FIG. 7 VARIATION OF CaCO_3 WITH PHI MEDIAN DIAMETER

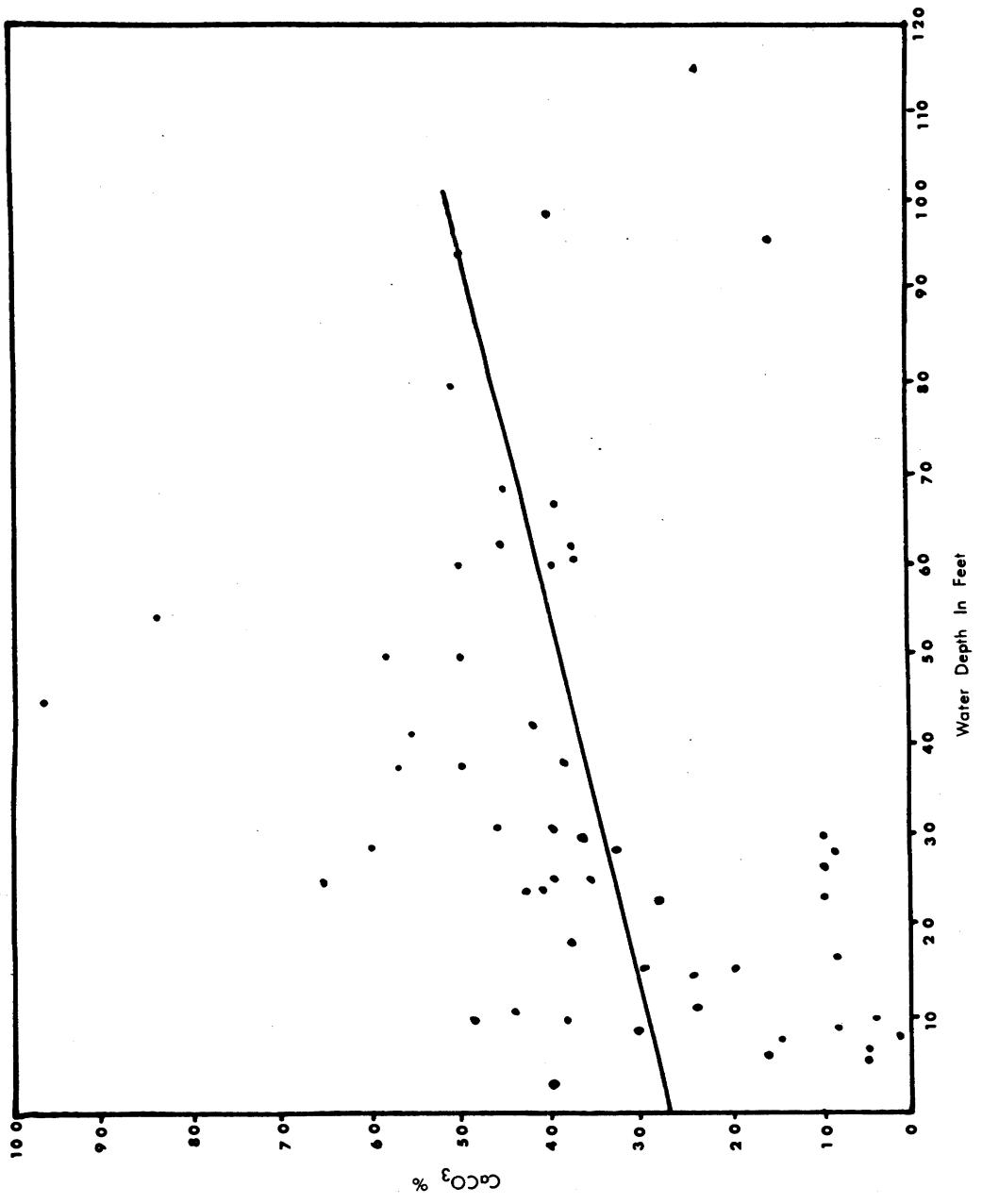


FIG. 8 VARIATION OF CaCO_3 WITH WATER DEPTH

vigorous bubbling, during the reaction of CaCO_3 with the HCl, material other than CaCO_3 which might react with the HCl and escape of water vapor.

INTERPRETATION OF THE DISTRIBUTION OF CALCIUM CARBONATE

Clearly the distribution of equivalent CaCO_3 in Mullet Lake is irregular (Fig. 3). Since there are no data pertaining to other chemical and organic properties of the lake, interpretations based on other factors must necessarily be intuitive and uncertain.

In general the percentage of equivalent CaCO_3 increases with depth and correspondingly with a decrease in median diameter; however, this increase is erratic (Fig. 6,7) and there are many local near-shore areas where the percentage of CaCO_3 is very high. In addition there are several areas lying in deep water where the percentage of CaCO_3 is unusually low. One reason for abnormally high CaCO_3 content in some sand areas is the presence of shell fragments. If the CaCO_3 in the fine grained sediments exists primarily as minute shell fragments or as fine grained calcareous material derived from the surrounding till then the increased content in this size fraction is due to the accumulation of this material in these relatively undisturbed areas. The low CaCO_3 content in some areas where clay size

sediments are accumulating is puzzling, and the writer can think of no reasonable explanation.

CONCLUSIONS

The distribution of sediments in Mullet Lake is affected by several factors including position of river inlets, distribution of glacial deposits within the basin, presence of springs and water depth. The manner in which they affect the distribution is summarized below.

- (1) The distribution of silt and clay is affected by the position of river inlets, most of the silt apparently being washed into the lake from the surrounding region.
- (2) The irregular width of the near-shore sand zone is attributed primarily to compositional differences of the shore and near-shore material. Thus most of the sand originates from the adjacent land by the shoreline processes of wave and current action.
- (3) A small sand area lying in the deep water offshore from Long Point may owe its origin to the agitating action of spring water emanating from the groundwater at this location.
- (4) The calcium carbonate in the sediments may have been derived from limestone and dolomite fragments in the

glacial deposits and from shell fragments of mollusks populating the beach and near-shore terrain.

(5) The carbonate content tends to increase although quite irregularly with increase in phi median and with increase in water depth.

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